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SYNOPSIS AND CRITIQUE OF THE AVAILABLE FORECASTS OF SOCKEYE SALMON (Oncorhynchus nerka) RETURNING TO BRISTOL BAY IN 1984

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ABSTRACT

This report reviews forecasts of the return of sockeye salmon to Bristol Bay, Alaska in 1984 made by the Alaska Department of Fish and Game (ADF&G), Japan, and the Fisheries Research Institute at the University of Washington. Individual ADF&G river system forecasts by age class are discussed in detail, and issues involving forecast reliability and consistency are addressed.

KEY WORDS: salmon forecasting methods, salmon population modeling, Bristol Bay sockeye salmon

INTRODUCTION

This report is a synthesis of several independent forecasts of the returns of sockeye salmon to Bristol Bay in 1984, together with confidence intervals, relative accuracy, and a critique of each forecast method. The forecast methods considered are: 1) the standard forecast made by the Bristol Bay research staff, Alaska Department of Fish and Game (ADF&G); 2) a forecast based on the Bristol Bay return of sibling age classes in 1983; 3) a forecast based on the arithmetic mean catch per effort from variable-mesh gillnet sampling by Japanese research vessels south of the Aleutian Islands; 4) a forecast based on the geometric mean catch per effort from variable-mesh gill net sampling by Japanese south of the Aleutian Islands; 5) a forecast based on a relation between estimated total Bristol Bay parent escapement, mean June air temperature at Cold Bay during the two years prior to year of return and total Bristol Bay return; and 6) a forecast based on a relationship between the mean air temperature in 5 above and the mean length of 2-ocean immature sockeye salmon caught in the Japanese gill net sampling south of the Aleutians. Throughout this paper the Gilbert-Rich method of age designation for salmon is used. The first digit is the total age; the second, subscripted digit is the number of years spent in fresh water.

METHODS

Standard ADF&G Forecast

The ADF&G forecast attempts to forecast by river system and major age class (4_2, 5_3, 5_2, 6_3) within river system based on a variety of techniques. The first method assumes a return per spawner based on either an escapement-return relationship specific to an individual river system, or by analysis of recent observed return per spawner for the particular river system. The predicted returns from the parent escapement (1978, 1979, and 1980 brood years) based on the assumed return per spawner (R/S) are partitioned into the component age classes by the historical mean or peak-year mean proportion of the particular age class returning. This method is hereafter referred to as forecasting by return per spawner (R/S). The second method is based on the return of younger sibling age classes from the same brood year. Two techniques are used: The first uses a linear regression model of the forthcoming return of the older sibling age class based on the return of the younger sibling age class the year before, fit to historical data. In the second technique, the return of the younger sibling age class is multiplied by the ratio of the return of the older sibling age class to the return of the younger sibling age class. These techniques are hereafter referred to as the method of forecasting by the return of sibling age classes. The third method is based on smolt studies. These studies are available only for the Kvichak and Wood River systems. There are three techniques used: The first multiplies the estimated number of smolts leaving the river system by the mean proportion surviving to return as adults. For 4_2 and 5_3 in the Kvichak the proportion surviving increases with mean June air temperature at Port Heiden during the year of smolt outmigration (Yuen 1979). The proportion surviving for these age classes is appropriately adjusted for year-to-year variation in temperature. The second technique of forecasting based on smolt studies is the product of the numbers of outmigrating smolts, the average marine survival and the average ocean age proportion. In

the Wood River system the ocean age proportion is very close to the ocean age proportion of the parent escapement of the smolt outmigration and is used as the estimate of the ocean age proportion of the returning adults from the population of smolt outmigrating.

The third technique of forecasting based on smolt data is the product of the fresh water age composition of the smolt outmigration observed from the brood year of interest, the expected return from the brood year based on R/S, and the mean ocean age proportion. These techniques will be hereafter referred to as the method of forecasting based on smolt data.

Several methods are then available for forecasting returns for each river system and age class within river systems. The results of each of the major methods (i.e., forecasting by R/S, return of sibling age classes, and smolt data), if available, are simply averaged and therefore weighted equally. If more than one estimate is available within a major method, those are averaged to give one result for the major method. In some cases a result for a major method is excluded in the final averaging process. The reationale for those exclusions is detailed in a separate section of this report.

Forecast Based on Japanese High Seas Sampling

The Japanese have been sampling a series of stations south of the Aleutian Islands during the summer months June through early August with variable mesh gill nets since 1972, (Takagi and Ito 1980). These catch data may be used to estimate relationships between mean catch per unit effort (CPUE) of 1-ocean immature and 2-ocean immature, and the subsequent return of 2-ocean mature and 3-ocean mature sockeye salmon to Bristol Bay the following year, respectively. Two methods for analysis of the catch data have been used. The first method uses the arithmetic mean of the catch per unit effort among sampling stations and the second method uses the geometric mean CPUE among sampling stations. The arithmetic mean was used in the ADF&G analysis of and forecast based on the Japanese data (Yuen 1982) and the geometric mean was used the University of Washington Fisheries Research Institute (FRI) analysis of and forecast based on the Japanese data (Rogers 1982).

Forecast Based on an Escapement-Temperature Model

The following empirical model relating observed return to estimated parent escapement and mean June air temperature at Cold Bay during the period of ocean residence of the returning fish was used to forecast total Bristol Bay return.

$$\ln(R_i) = A + B_1 \ln(E_i) + B_2 \ln(T_i)$$

where R_i is the return in year i, E_i is the estimated parent escapement of the return in year i, T_i is the mean of the two mean June air temperatures at Cold Bay during year i-1 and i-2, and A, B_1, B_2 are constants determined by least-squares fit to past data. The parent escapement for return in year i was estimated by summing the escapements in year i-6, i-5, i-4 multiplied by the mean proportion (taken over the years 1965-1982) of the return that were 6, 5, and 4-year-old fish, respectively. These proportions are remarkably consistent from year to year except for peak years which tend to have more 5-year-old fish returning.

Forecast Based on a Temperature-Length Model

The following empirical model relating observed returns to mean June air temperature at Cold Bay during the period of ocean residence of the returning fish and the mean length of 2-ocean immatures caught in the Japanese high seas gill net sampling was used to forecast total Bristol Bay return.

$$ln(R_i) = A + B_1 ln(T_i) + B_2 ln(L_i)$$

where R_i is returns in year i, T_i is the mean of the two mean June air temperatures at Cold Bay during year $i-1$ and $i-2$, L_i is mean length of 2-ocean immatures caught in the Japanese high seas gill net sampling during year $i-1$ and A, B_1, B_2 are constants determined by least-squares methods.

Forecast Based on Return from Sibling Age Classes the Previous Year

The method of forecasting based on return from sibling age classes, described in the methods section describing the standard ADF&G forecast was used to forecast return in 1984. The past returns from the various Bristol Bay river systems were pooled. Simple linear regression models relating the returns of 4_2 to the returns of 3_2 the previous year, the returns of 5_3 to the returns of 4_3 the previous year, the returns of 5_2 to the returns of 4_2 the previous year, and the return of 6_3 to the returns of 5_3 the previous year were fit to the pooled Bristol Bay return data.

Confidence Limits

Confidence limits and the standard deviation were estimated for each of the major forecasting methods by analysis of the performance of each of the methods in forecasting past returns to Bristol Bay. A simple linear regression model relating observed to forecast returns was fit to past data (Table 1). Confidence intervals around the regression line were estimated by standard techniques (Sokol and Rohlf 1969).

RESULTS OF THE ADF&G FORECAST

Presented below is a narrative of the results of the various ADF&G forecasting techniques (Table 2) used to generate specific forecasts for individual river systems and age classes within river systems. Presented for each of the major river systems (Kvichak, Naknek, Egegik, Ugashik, Wood, Igushik, Nuyakuk, and Togiak) are the details of how the forecasts were made, and how, in situations where more than one forecast was available, the several forecasts were averaged or excluded to give the final value. Areas of concern are identified by inconsistencies in results of alternative forecasting techniques. These issues are presented by river system and by age class within river system. Summaries of forecasts made by return per spawner are given in Table 3; forecasts of the returns based on return of sibling age classes in 1983 (i.e., using the return of sibling age class forecasting method) are given in Table 4; and forecasts based on smolt data are given in Tables 5 and 6.

Table 1. Comparisons of various forecast methods, Bristol Bay, 1961-1983.

Year	ADF&G[1]	Japanese Sampling[1]		Escapement Temperature Model[2]	Temperature Length of 2-Ocean Immature Model[2]	Bay Wide Return from Sibling Classes[2]		
		Arithmetic Mean	Geometric Mean				Inshore	Total
1961	43.6	-	-	-	-	33.2	18.1	23.9
1962	19.6	-	-	-	-	11.6	10.4	11.3
1963	8.6	-	-	-	-	12.4	6.9	7.8
1964	17.4	-	-	-	-	13.8	10.9	11.2
1965	27.8	-	-	37.4	-	26.7	53.1	60.0
1966	31.3	-	-	18.3	-	21.1	17.5	19.4
1967	13.7	-	-	9.0	-	11.6	10.3	11.2
1968	10.4	-	-	11.0	-	15.0	8.0	8.8
1969	21.3	-	-	25.0	-	27.3	19.0	21.0
1970	55.8	-	-	44.2	-	61.2	39.4	43.3
1971	15.2	-	-	37.2	-	18.8	15.8	17.8
1972	9.7	-	-	9.7	-	13.6	5.4	6.6
1973	6.2	8.3	10.7	4.3	4.2	10.7	2.4	3.1
1974	5.0	6.1	8.5	9.4	9.4	11.5	10.9	11.4
1975	12.0	21.4	22.5	19.8	16.9	16.3	24.2	25.4
1976	12.0	22.1	18.5	19.0	18.3	17.0	11.5	12.4
1977	8.4	18.9	23.1	8.0	8.2	12.3	9.7	10.4
1978	11.5	22.5	16.7	13.9	21.8	14.3	19.9	20.2
1979	22.7	22.2	25.6	44.8	49.7	50.6	39.9	40.2
1980	54.5	64.1	65.4	68.4	49.8	47.2	62.3	62.9
1981	26.7	29.0	21.3	34.7	28.8	48.2	34.5	35.3
1982	34.6	29.4	24.3	19.8	30.7	14.4	22.4	22.5
1983	27.1	37.1	44.2	27.7	46.3	31.2	45.4	45.7

[1] Forecast is inshore return.

[2] Forecast is total return, including estimated Japanese catch.

Table 2. Forecast (thousands of fish) of the 1983 Bristol Bay sockeye salmon run, based on standard ADF&G methods.

District/System	Age Class (Brood Year) 4_2 (1980)	5_3 (1979)	Age Class (Brood Year) 5_2 (1979)	6_3 (1978)	Total
Naknek/Kvichak District					
Kvichak River	6,041	7,314	2,982	367	16,704
Branch River	209	99	161	53	522
Naknek River	595	895	2,549	1,090	5,129
Total	6,845	8,308	5,692	1,510	22,355
Egegik District	354	1,917	973	2,844	6,088
Ugashik District	394	1,476	1,177	249	3,296
Nushagak District					
Wood River	1,353	481	2,492	258	4,584
Igushik River	347	184	856	52	1,439
Nuyakuk River	563	81	1,999	42	2,685
Nushagak-Mulchatna	87[2]	5	141	27	260
Snake River	23	2	4	1	30
Total	2,373	753	5,492	380	8,998
Togiak District	203	67	454	55	779
Total Bristol Bay[1]	10,169	12,521	13,788	5,038	41,514

[1] Sockeye salmon of several minor age classes would be expected to contribute an additional 1 to 2% to the total return.

[2] Includes 4_1 age class.

Table 3. Summary of forecasts made by return per spawner, Bristol Bay, Alaska.

System	Age Class	Parent Escapement	Assumed Return per Spawner	Assumed Proportion of Respective Age Class in Return	Predicted Return
Kvichak	4_2	17.500[1]	1.65	.2214	6.393
	5_3	11.218	1.70[2]	.5536	10.546
	5_2	11.218	1.70[2]	.1038	1.977
	6_3	4.149	1.05[3]	.1060	0.461
Naknek	4_2	2.645	1.92	.1400	0.710
	5_3	0.925	4.03	.2859	1.066
	5_2	0.925	4.03	.2910	1.085
	6_3	0.813	5.01[3]	.2685	1.092
Egegik	4_2	1.061	4.73	.0683	0.347
	5_3	1.032	4.81	.4608	2.289
	5_2	1.032	4.81	.1094	0.543
	6_3	0.896	10.43[3]	.3047	2.844
Ugashik	4_2	3.321	0.68	.1978	0.443
	5_3	1.701	3.22[2]	.4465	2.446
	5_2	1.701	3.22[2]	.1989	1.089
	6_3	0.070	22.30[3]	.1429	0.226
Wood	4_2	2.969	1.46	.4559	1.976
	5_3	1.706	3.73[2]	.0982	0.625
	5_2	1.706	3.73[2]	.371	2.362
	6_3	2.267	1.33[3]	.0350	0.106
Igushik	4_2	1.988	0.83	.2100	0.347
	5_3	0.860	1.76[2]	.1218	0.184
	5_2	0.860	1.76[2]	.5527	0.838
	6_3	0.536	0.83[3]	.1045	0.046
Nuyakuk	4_2	3.027	1.00	.1860	0.563
	5_3	0.360	4.42[2]	.0512	0.081
	5_2	0.360	4.42[2]	.6747	0.073
	6_3	0.577	2.01[3]	.0458	0.055
Togiak	4_2	0.462	1.71	.2556	0.203
	5_3	0.171	3.79	.1030	0.067
	5_2	0.171	3.79	.5170	0.335
	6_3	0.274	2.58	.0868	0.061

[1] Parent escapement, 1980, reduced by 5 million due to velocity barrier to upstream migration caused by high runoff.

[2] R/S based on returns to date divided by 1 - the long term proportion of 4_2, 5_3, 5_2, in return.

[3] R/S based on returns to data divided by 1 - the long term proportion of 6_3, in return.

Table 4. Summary of Bristol Bay sockeye return forecasts based on returns of sibling age classes in 1983.

4_2 on 3_2

System	Correlation Coefficient	#3_2 in 1983	Rank	Forecast of 4_2 in 1984
Kvichak	.483	2,325	9	3,613,000
Naknek	.333	1,398	8	480,000
Egegik	.923	1,086	4	361,000
Ugashik	.911	587	4	345,000
Wood	.190	1,296	11	1,101,000
Igushik	N/A			
Nuyakuk	N/A			
Togiak	N/A			
Baywide	.610	7,578	14	3,698,000

5_3 on 4_3

System	Correlation Coefficient	#4_3 in 1983	Rank[1]	Forecast of 5_3 in 1984
Kvichak	.881	74,451	4	8,162,000
Naknek	.403	3,917	12	724,000
Egegik	.451	6,993	4	1,545,000
Ugashik	.457	7,676	4	506,000
Wood	N/A			
Igushik	N/A			
Nuyakuk	N/A			
Togiak	N/A			
Baywide	.728	93,037	7	10,425

5_2 on 4_2

System	Correlation Coefficient	#4_2 in 1983	Rank[1]	Forecast of 5_2 in 1984
Kvichak	.8806	17,631,000	1	5,049,000
Naknek	.575	2,346,000	0	4,013,000
Egegik	.953	706,000	2	1,077,000
Ugashik	.645	2,795,000	1	1,273,000
Wood	.497	2,801,000	1	1,560,000
Igushik	.873	318,000	4	873,000
Nuyakuk	.911	378,000	1	2,642,000
Togiak	.723	251,000	1	493,000
Baywide	.728	27,488,000	1	15,472,000

-Continued-

Table 4. Summary of Bristol Bay sockeye return forecasts based on returns of sibling age classes in 1983 (continued).

6_3 on 5_3

System	Correlation Coefficient	#5_3 in 1983	Rank[1]	Forecast of 6_3 in 1984
Kvichak	.779	1,203,000	17	248,000
Naknek	.499	1,023,000	6	803,000
Egegik	.661	5,623,000	0	2,259,000
Ugashik	.860	756,000	3	209,000
Wood	.313	561,000	1	157,000
Igushik	.383	64,000	11	58,000
Nuyakuk	.683	113,000	11	26,000
Togiak	.594	53,000	8	37,000
Baywide	.806	9,416,426	6	1,448,000

[1] Rank is the number of years since 1956 that have had a higher number of fish returning.

Table 5. Summary of Bristol Bay sockeye return forecasts based on smolt studies.

System	Age Class	# Smolt (Millions)	Assumed Proportion Returning	Forecast (Millions)	Assumed Marine Survival	Assumed Ocean Age Proportion	Forecast (Millions)
Kvichak	4_2	122.928	.069	8.507	.081	.779	7.728
	5_3	81.113	.075	6.109	.1080	.779	6.824
	5_2	162.958	.019	3.058	.081	.221	2.906
	6_3	20.653	.028	0.580	.108	.221	0.492
Wood	4_2	32.350	-	-	.057	.517	1.910
	5_3	4.710	-	-	.063	.922	0.275
	5_2	64.330	-	-	.057	.517	1.910
	6_3	33.200	-	-	.063	.304	0.638

Table 6. Summary of Bristol Bay sockeye return forecasts made based on a combination of smolt studies and return per spawner.

System	Age Class	Assumed Return from Parent Escapement (Millions)	Proportion Respective Freshwater Age in Resulting Smolt	Respective Ocean Age Proportion	Forecast (Millions)
Kvichak	4_2	N/A			
	5_3	N/A			
	5_2	N/A			
	6_3	4.349	.113	.221	0.108
Wood	4_2	N/A			
	5_3	6.371	.068	.9217	0.400
	5_2	6.371	.932	.5170	3.069
	6_3	3.025	.418	.304	0.383

Kvichak

Analysis of historical return per spawner has shown no consistent trend in R/S. Consequently, returns per spawner based on a Ricker escapement-return relationship fit to all years of data available (i.e., since the 1956 brood year) were used. The 1980 parent escapement enumerated at the Kvichak tower was reduced by 5 million to account for documented (Poe and Mathisen 1980) mortality of adult sockeye prior to spawning due to a velocity barrier to upstream migration on the Newhalen River due to high flows.

4_2:

There were large disparities between the forecast based on sibling regression (Table 4), and those based on R/S and smolt data (Tables 5 and 6). The return of 3_2s (2,325) was mediocre in 1983. The forecast based on the return of 3_2 jacks was 3.6 million. The forecast based on R/S was 6.4 million. The average of the two available smolt forecasts was 8.1 million. These 3 forecasts were averaged giving a final figure of 6.0 million.

5_3:

The forecast based on R/S was 10.6 million. This forecast was not used because of uncertainty regarding the R/S for the 1979 brood year. Returns to date from the 1979 parent escapement of 11.2 million are approximately 92% of the total return projected based on the escapement-return curve. In addition to this, the high return (17.6 million) of 4_2s is very unusual for the Kvichak. Use of the average age composition of returns from brood year escapement will probably not be indicative of the age composition eventually observed for the 1979 brood year return. The final forecast of 7.3 million was an average of the 8.2 million forecast based on the moderate return of 4_3 jacks, and the 6.5 million forecast based on smolt studies.

5_2:

For the same reasons discussed in the 5_3 forecast above, the forecast based on R/S was not considered in the final 5_2 forecast. The forecast (5.0 million) based on the very large return of 4_2s in 1983 was averaged with the forecast based on smolt data (3.0 million) giving a final forecast of 4.0 million.

6_3:

The final figure of 0.37 million was an average of the forecasts based on R/S (0.40 million), return of 5_3s in 1983 (0.25 million), and smolt data (0.39 million).

Kvichak Synopsis. The Department of Fish and Game has been unable to forecast the returns to the Kvichak accurately in recent years. Returns to the Kvichak were considerably below forecast in 1981 and 1982, while considerably above forecast in 1983. The ability to forecast accurately the returns of sockeye to the Kvichak depends on the ability to predict peak years and non-peak years. In the past both R/S and age composition vary greatly among peak and non-peak brood years. In the past, returns from peak year escapements have shown higher

return per spawner and a much higher proportion of 5_3s than non-peak years. Although 1983 was thought to be the traditional low year in the Kvichak cycle, more than 20 million sockeye returned to the Kvichak. It is useful to consider the evolution of long-term forecasts as relevant data emerges with recent smolt studies and returns. More recent information suggests that the cycle is changing with the peak year likely to be 1984 with a possibility that it was 1983 rather than 1985.

There are two techniques currently available for making long term projections of returns to the Kvichak River. The first allows a 4-year-ahead forecast based on the method of R/S (Table 7). The second allows a 2-year-ahead forecast based on the smolt data (Table 8). The earliest that a forecast could be made for the period 1983-1985 based on the method of R/S would be following the return of adult sockeye in 1981. The earliest that a forecast could be made for the period 1983-1985 based on smolt data would be following the enumeration of the 1983 smolt outmigration. Below are presented four different forecasts for the returns to the Kvichak, 1983-1985. The first (henceforth called Method 1) makes use of the oldest information, and assumes peak year characteristics (i.e., the proportion of 4_2, 5_3, 5_2, and 6_3 in the returns being 0.20, 0.67, 0.04, 0.05, respectively; and projected returns based on a Ricker escapement-return curve fit through past peak year returns) for the 1980 brood year and non-peak year characteristics (i.e., the proportions of 4_2, 5_3, 5_2, and 6_3 in the returns being 0.23, 0.51, 0.12, and 0.12, respectively; and the projected returns based on a Ricker escapement-return curve fit through the past non-peak year returns) for 1977, 1978, 1979, and 1981. The long-term forecast based on assumptions in Method 1 shows a clear peak year return for 1985 (Table 9). However, returns in 1983 were four times that forecast based on Method 1. This was due in part to a much greater return per spawner from the 1979 brood year than that forecast based on non-peak return per spawner.

If one assumes peak year characteristics for the 1979 as well as the 1980 brood years (Method 2) then the forecast shows that comparably large returns occur in both 1984 and 1985. But the forecast 1983 return based on assumptions in Method 2 is less than half the actual return in 1983. The assumed 3-year freshwater age component of the returns in both Method 1 and Method 2 forecasts was much greater than observed in the smolt outmigrations for both the 1979 and 1980 broods. Method 3 allocates the freshwater age of the returns based on the method of R/S assuming peak year production for both the 1979 and 1980 broods using the freshwater age composition of the respective smolts produced. The projected returns based on Method 3 show a clear peak in 1984 with comparable returns for 1983 and 1985.

The last method (Method 4) for forecasting returns in 1983-1985 projects returns from the estimated smolts produced from the 1977-1981 brood year escapements. The method assumes that the marine survival for the one-check and two-check smolts is 0.0807 and 0.108, respectively. The ocean-age proportion of the smolts produced from the 1979 and 1980 brood year escapements reflects that of past peak years while the ocean-age proportion of the smolts produced from other relevant brood-year escapements reflects those of past non-peak years. The forecast based on assumptions of Method 4 shows a peak year in 1984 with a slightly smaller 1983 return, and a relatively weak 1985 return (Table 9). The observed 1983 return was larger than the forecasted return based on Method 4 and even larger than the peak return based on Method 4.

Table 7. Information used for a 4-year-ahead forecast based on R/S methods for the Kvichak River.

Brood Year	Cycle Year[1]	Escapement (Thousands) S	R/S	Total Return	Projected Return by Age Class (Thousands) 4_2	5_3	5_2	6_3
1977	N	1,342	1.86	2,495	-	-	-	297
1978	N	4,149	1.23	5,102	1,194	2,638	643	607
1979	N	11,218	0.38	4,251	995	2,198	535	506
1979	C	11,218	2.81	31,506	6,305	21,249	1,387	1,450
1980	C	17,505	2.18	38,234	7,647	25,770	1,682	1,759
1981	N	1,755	1.76	3,094	1,724	1,600	390	368
1982	N	1,135	1.90	2,162	506	-	-	-

[1] C indicates peak year attributes were assumed.

N indicates non-peak year attributes were assumed.

Table 8. Information used for 2-year-ahead forecast based on smolt data for the Kvichak River.

Brood Year	# Age I Smolts (Thousands)	%	# Age II Smolts (Thousands)	%	Projected Return by Age Class (Thousands)			
					4_2	5_3	5_2	6_3
1977	26,623	72.4	10,110	27.6	-	-	-	272
1978	162,564	88.7	20,653	11.3	9,852	1,675	3,267	555
1979	162,958	66.8	81,113	33.2	11,494	7,656	1,657	1,104
1980	122,928	57.7	90,000	42.3	8,670	8,495	1,250	1,224
1981	10,000	-	-	-	606	-	-	-

Table 9. Available long term forecasts for Kvichak River (returns are in thousands of fish).

Forecast Method	Year	Forecast Return 4_2	5_3	5_2	6_3	Total
R/S assuming peak year characteristics for 1980 brood year, and non-peak characteristics for 1977, 1978, 1979, 1981, 1982 brood years.	1983	995	2,638	647	296	4,576
	1984	7,647	2,198	535	607	10,987
	1985	724	25,770	1,682	500	28,676
	1986	506	1,600	390	1,759	4,255
R/S assuming peak year characteristics for 1980, 1979, brood years and non-peak characteristics for 1977, 1978, 1981, 1982 brood years.	1983	6,305	2,638	643	297	9,883
	1984	7,647	21,249	1,387	607	30,890
	1985	724	25,770	1,682	1,450	29,629
	1986	506	1,600	390	1,759	4,255
R/S but using relative freshwater ages in smolts produced from brood year to allocate projected returns to freshwater age using peak year characteristics for 1979 and 1980 brood years and non-peak characteristics for other years.	1983	18,406	1,126	433	171	20,136
	1984	19,281	9,148	2,653	144	31,226
	1985	<1,000	14,135	2,780	1,319	<19,234
Using smolt data	1983	11,494	1,675	3,267	272	16,708
	1984	8,670	7,656	1,657	555	18,538
	1985	606	8,495	1,250	1,104	11,455

Additional data is now available to evaluate the long term forecast based on smolt data. Firstly, there was a weak return of 3_2 jacks in 1983 and a moderate return of 4_3 jacks. The forecast of 4_2 in 1984 based on return of 3_2 in 1983 is lower than the smolt forecast, while the forecast of 5_3s based on return of 4_3s is comparable to the smolt forecast. Secondly, the forecast based on the Japanese high seas gill net sampling indicates a relatively weak return to Bristol Bay in 1984. The data indicates an extremely weak return of 2-ocean fish bay-wide, with 4_2s being only 25% of the 2-ocean return. Dr. Donald E. Rogers, Fisheries Research Insitute (personal communication) has analysed the distribution of Japanese sampling effort relative to past years and feels that the Japanese were south of the traditional sampling area. The distribution of sampling effort would tend to under-represent the 1-ocean immatures based on past spatial distribution of 1-ocean immatures in the Adak purse seine sampling conducted by FRI. Nevertheless, Rogers feels that the 3-ocean return forcast based on the Japanese high seas sampling is accurate. The low forecast based on the Japanese sampling is cause for concern. If the low 2-ocean return forecast based on the Japanese high seas sampling occurs in 1984, the Kvichak will have a return lower than the peak year escapement goal.

Naknek

The observed return per spawner since the 1970 brood year has ranged from 1.79 to 6.01. There does not appear to be any decreasing trend in return per spawner over time in the Naknek system. There is a slight depression in R/S at high escapements. The escapements in 1978, 1979 were moderate, while the escapement in 1980 was large (2.6 million). The assumed R/S for these escapements were 5.01, 4.03, and 1.92, respectively. These were based on simple linear regression of R/S against escapements for the 1970-1978 brood years.

4_2, 5_3, and 6_3:

The forecast based on R/S and that based on the return of sibling age classes were very consistent for each of these age classes. The final forecasts of 0.6 million 4_2s, 0.9 million 5_3s, and 1.1 million 6_3s were simple averages of the forecasts made based on these two methods.

5_2:

There was inconsistency in the forecasts based on R/S (1.1 million) and the forecast based on the large return of 4_2s in 1983 (4.0 million). The final forecast (2.6 million) was an average of these two numbers. This inconsistency, however, points to a key area to watch in the Naknek in 1984.

A smolt enumeration project using sonar smolt counters developed from the long term projects that have been in place on the Kvichak and Wood Rivers was initiated on the Naknek in 1982. Because of the novel nature of the project the derived estimates cannot be considered reliable. However, 116 million one-check and 13 million two-check smolts were enumerated in 1982. These estimates suggest that the production from the large 1980 escapement was good and may indicate a larger return of 4_2s in 1984 than forecast.

Egegik

Observed R/S since the 1969 brood year have ranged from 1.34 to 9.87. There was a clear decrease in R/S with increasing escapement 1969-1977. However, the projected returns based on the limited returns to date from the 1978 and 1979 brood years were greater than 10. The high returns per spawner have occurred for relatively large escapements of .89 and 1.06 million fish for 1978 and 1979, respectively. The assumed R/S for the 1979 and 1980 brood years were estimated by a regression of R/S against S for the years 1969-1970. These values were 10.43, 4.81, and 4.73 for the 1978, 1979, and 1980 brood years, respectively. The assumed R/S for 1978 was projected from the returns to date.

4_2, 5_3, and 6_3:

The forecast returns in 1984 based on R/S and returns of sibling age classes in 1983 were very consistent for these age classes. The final forecasts of 0.35 million 4_2s, 1.9 million 5_3s, and 2.8 million 6_3s were averages of these two forecasts.

5_2:

There was inconsistency in the forecast based on R/S (0.54 million) and the forecast based on the return of 4_2s in 1983 (1.4 million). The final (0.97 million) forecast was an average of these two forecasts, but the inconsistency points to an area to watch closely in 1984.

As with the Naknek system, a sonar smolt counting project was initiated in 1982. The estimates of the 1982 smolt outmigration derived from this project cannot yet be considered reliable, due to the novel nature of the project. However, 49.5 million one-check smolts and 14.3 million two-check smolts were enumerated. Historically, Egegik has produced a much higher proportion of 3-year freshwater age fish (81.2%) than 2-year freshwater age fish. Therefore, the relative magnitudes of 4_2s and 5_3s in the forecasted return in 1984 is inconsistent with the freshwater age composition for the 1982 smolt outmigration. If the age composition of the 1982 Egegik smolt outmigration is correct then the return of 4_2s will likely be much higher than forecast and the return of 5_3s in 1984 will probably be much lower than forecast.

Ugashik

The R/S has been very high in the Ugashik system in recent years. The R/S for the 1974-1978 brood years have ranged from 9.12-22.30. Escapements have been low through that period, ranging from 0.062 to .430 million. Escapements for the 1979 and 1980 brood years were 1.7 and 3.3 million, respectively. Based on the limited returns of the 4_2 age class in 1983 and the historical average proportion of 4_2s in the returns, the R/S from the large 1979 escapement is 3.2. Although high relative to other Bristol Bay river systems this is a dramatic decrease in R/S relative to earlier brood years in the Ugashik system. The R/S used to project returns from the 1979 and 1980 escapements was based on a regression of the logarithm of R/S against S for the years 1974 through 1979. Note that the projected R/S from the 1979 brood based on limited returns to date was used in the regression. The values for R/S estimated for 1979 and 1980 were 3.29 and 0.68, respectively.

4_2, 5_2, and 6_3:

The forecasted returns in 1984 based on the method of R/S and returns from sibling age classes in 1983 were very consistent for these age classes. The final forecasts of 0.39 million 4_2s, 1.18 million 5_2s, and 0.25 million 6_3s were averages of the forecasts based on these two methods.

5_3:

There was inconsistency in the forecast based on R/S (2.45 million) and the forecast based on return of 4_3s in 1983 (0.51 million). The final forecast (1.48 million) was an average of these two methods. This inconsistency points to a key area to watch in 1983.

The first returns from the record level escapement in 1980 will occur in 1984. A low R/S to project returns was assumed for this large parent escapement based on the apparent decline in R/S from the 1979 brood year. This decline was estimated from an estimate of the proportion of 4_2s which has been quite variable in the past. The return of 4_2s in 1983 was 2.8 million was the major component in the largest run to Ugashik since 1960. A smolt project using sonar smolt counters was initiated in 1983. There was a surprisingly large outmigration of three-year-old smolts from the large 1980 escapement. Preliminary estimates are in the neighborhood of 50 million 2-check smolts produced. This indicates good survival from the 1980 escapement, with perhaps less depression of R/S due to high spawner density than was assumed to project 1984 returns. There is a potential for a larger return to Ugashik than forecast. The forecast of 4 and 5-year-old returns to Ugashik is weak and returns of these age classes should be closely monitored in 1984.

Wood River

Observed R/S from the 1970-1977 brood years have ranged from 1.49-6.49. The projected returns for the 1978 and 1979 brood years based on returns to date were 1.33 and 3.96, respectively. These data show a clear depression in R/S at high escapements. The escapements in 1978 and 1980 were the second largest and largest escapements since escapement enumeration began in the fifties. The natural logarithm of R/S was regressed against escapement for the 1970-1978 brood years to estimate R/S for the 1980 brood year, giving a value of 1.46 for the projected R/S for the 1980 brood year. The projected R/S based on returns to date was assumed for the 1978 and 1979 brood years.

The forecasts based on R/S, the return of sibling age classes in 1983, and on smolt data were very consistent. The final forecasts of 1.35 million 4_2s, 0.48 million 5_2s, 2.49 million 5_2s, and 0.26 million 6_3s are averages of the forecasts based on these three methods.

Igushik

Observed R/S from the 1970-1977 brood years have ranged from 0.90-15.96. The projected R/S for the 1978 and 1979 brood years based on returns to date were 0.83 and 1.86, respectively. There is an almost precipitous decrease in R/S with increasing escapements in the Igushik system. The low R/S observed based

on returns to date for 1978 and 1979 are consistent with this pattern. The escapements in 1978-1980 were 0.54, 0.86, and 1.99 million, respectively. The 1980 escapement was a record escapement to date. Except for 1979 (the estimated R/S based on returns of 4_2s in 1983) the observed R/S for escapements over .5 million have been less than 1 and averaged 0.8. That value was used to project returns from the 1980 brood. The estimated R/S based on the limited returns to date was used for the R/S for the 1978 and 1979 broods.

4_2 and 5_3:

The Igushik system produces almost no jacks, consequently the method based on return of jacks was not available to forecast returns of 4_2s and 5_3s. The forecasts based on R/S for 4_2 and 5_3 were 0.35 and 0.18 million, respectively.

5_2 and 6_3:

The forecast based on R/S and returns from sibling age classes in 1983 was very consistent for these age classes. The final forecast of 0.86 million 5_2s and 0.52 million 6_3s was an average of the forecasts based on these two methods.

Nuyakuk

Observed R/S from the 1970-1977 brood years have ranged from 2.34 to 17.74. The projected R/S from the 1978 and 1979 brood years based on returns to date are 2.10 and 5.39, respectively. These were used to forecast returns from these brood years. There is a slight decreasing trend in R/S with increasing escapement. The parent escapement in 1980 was 3.0 million and greatly exceeded the previous record escapement (0.67 million) in 1975. There is no basis for projecting returns for an escapement of this magnitude based on returns from the past. A gues (R/S = 1) was used to project returns from the 1980 escapement. Fortunately the dominant age class in the Nuyakuk returns is 5_2 and will not return until 1985. The error in forecasting returns of 4_2s in 1984 will not be significant relative to the total return to Nuyakuk. The forecast returns of 4_2, 5_3, and 6_3 were 0.56, 0.08, and 0.042 million. The forecast of 4_2 and 5_3 were based on R/S while the forecast of 6_3 was an average of the forecasts based on R/S and the return of 5_3s in 1983.

5_2:

The forecast return of 5_2s was 2.0 million and was an average of the forecast based on R/S (1.1 million) and the forecast based on the large return of 4_2s in 1983 (2.9 million). This inconsistency points to another key area to watch in 1984.

Togiak

Observed returns per spawner from the 1968-1977 brood years have ranged from 1.77-6.61. The projected returns from the 1978 and 1979 brood years based on returns to date were 2.58 and 5.64, respectively. There is a slight decreasing trend in R/S with increasing escapement. The natural logarithm of R/S was regressed against S to estimate R/S for the 1979 and 1980 brood years, giving an estimated R/S of 3.79 and 1.71, respectively. Togiak produces very few jacks (both 3_2 and 4_3), consequently forecasts based on their return were not available. The forecasts for the returns of 4_2, 5_3, 5_2, and 6_3 were made based on R/S or an

average of the forecast based on R/S and returns of sibling age classes in the case of 5_2 and 6_3. Those forecasts for returns in 1984 (millions of fish) were 0.20, 0.07, 0.45, and 0.06 for 4_2, 5_3, 5_2, and 6_3, respectively.

SUMMARY AND CONCLUSIONS

The forecasts for the 1984 return of sockeye salmon to Bristol Bay made with the available methods detailed above ranged from 11.2 to 53.4 million (Table 10). A pooled forecast making use of all of this information was calculated from the average of the available forecasts weighted by the inverse of the variance (the standard deviation squared). In this forecast, the two available high seas forecasts were combined into one forecast. The pooled forecast of the total run to Bristol Bay in 1984 is 31.1 million.

Forecasts by major age class were available for four of the available forecasts (Table 11). The major difference between the standard ADF&G and the return from sibling age classes was the relatively low 4_2 component due to the low Bay-wide return of 3_2 jacks in 1983. The high seas forecast is much lower than either the standard ADF&G or the return of sibling age classes. The high seas forecast is dominated by 3-ocean returns; however, it is much lower than the other two forecasts. Particularly bleak are the 2-ocean returns in the high seas forecast, with 4_2s being roughly one-fourth as abundant as 5_3s.

The various pieces of information used to generate these available forecasts (Table 10) in the chronological order of their availability starting from the least recent to the most recent are: parent escapement, smolt outmigration estimates, returns from sibling age classes, and the length and CPUE of immature sockeye salmon in the Japanese high seas gill net sampling. In general the more recent the information the lower the return forecast based on that information. In view of this pattern and the fact that the standard pooled forecast was used as the forecast to present to the industry, the pooled forecast was allocated to age class and river system based on the following. The forecast to the Kvichak was taken to be that from the standard ADF&G method. It was felt that more recent information was considered in that forecast, since many forecasts based on return per spawner were dropped in view of apparent cycle changes to the Kvichak. The difference between the Kvichak forecast and the pooled total Bay forecast was allocated to the remaining age classes and river systems by relative abundance in the standard ADF&G forecast (Table 12). Unfortunately, if the actual returns in 1984 are significantly lower than the standard ADF&G forecast of 41.5 million, the age and river-system composition of the lower return will be very different from the pooled forecast allocated to age class and river system based on the above method.

This is not an ideal template from which to set early management decisions in 1984 and analyze anomalous age composition and river system run strengths that emerge in 1984. For this reason the synopsis of key areas to watch in 1984 are couched relative to the standard ADF&G forecast (Table 13).

In general, based on the high sea's data, a lower return of 3-ocean fish than that forecasted by the standard ADF&G methods is expected. The high seas forecast of the 2-ocean return needs to be clarified. Don Rogers (personal

Table 10. Summary of available forecasts of the 1984 return of sockeye salmon to Bristol Bay.

Forecast Methods	Forecast	Standard Deviation	Confidence Limits
Escapement Temperature Model	53.4	9.1	40.3 - 64.3
Standard ADF&G	41.5	11.8	21.6 - 53.6
Temperature Length of 2-Ocean Fish	24.9	7.4	14.8 - 36.0
Bay-wide Return [1] from Sibling Age Class	31.0	11.1	14.6 - 44.8
Japanese Gill Net [1] Sampling Geometric Mean	14.4	8.9	1.86 - 27.7
Japanese Gill Net [1] Arithmetic Mean	11.2	9.0	0 - 24.5
Pooled Estimate[2]	31.139	10.2	17.6 - 44.6

[1] Age composition available.

[2] The pooled estimate is the average of the individual estimates weighted by the inverse of the standard deviation squared.

Table 11. Total 1984 Bristol Bay sockeye forecast by major age class for each of the alternative forecast methods.

Forecast Techniques		4_2	5_3	Total 2-Ocean	5_2	6_3	Total 2-Ocean	Total
Standard ADF&G	# (Thousands)	10,169	12,521	22,690	13,788	5,031	18,826	41,514
	Percent	24.5	30.2	54.7	33.2	12.1	45.3	
Bay-wide Return From Sibling Age Classes	# (Thousands)	3,698	10,425	14,123	15,472	1,448	16,920	31,043
	Percent	11.9	33.6	45.5	49.8	4.7	54.5	
Japanese CPUE Arithmetic Mean	# (Thousands)	622	1,918	2,540	6,326	2,290	8,618	11,158
	Percent	5.6	17.2	22.8	56.7	20.5	72.0	
Japanese CPUE Geometric Mean	# (Thousands)	1,250	3,853	5,103	6,796	2,463	9,259	14,362
	Percent	8.7	26.8	35.5	47.3	17.2	64.5	

Table 12. Pooled 1984 Bristol Bay sockeye salmon forecast, allocated to age class and river system.

	Number of Fish in Thousands				
	Age Class (Brood Year)		Age Class (Brood Year)		
District/System	4_2 (1980)	5_3 (1979)	5_2 (1979)	6_3 (1978)	Total
Naknek-Kvichak District					
Kvichak River	6,041	7,314	2,982	367	16,704
Branch River	122	58	92	31	305
Naknek River	346	520	1,482	634	2,982
Total	6,509	7,892	4,558	1,032	19,991
Egegik District	206	1,115	566	1,654	3,541
Ugashik District	229	858	684	145	1,916
Nushagak District					
Wood River	787	280	1,449	150	2,666
Igushik River	202	107	498	30	837
Nuyakuk River	327	47	1,162	24	1,560
Nushagak-Mulchatna	51[2]	3	82	16	152
Snake River	13	1	2	1	17
Total	1,380	438	3,193	221	5,232
Togiak District	118	39	264	32	453
Total Bristol Bay[1]	8,442	10,342	9,265	3,084	31,133

[1] Sockeye salmon of several minor age classes are expected to contribute an additional 1-2 percent to the total return.

[2] Includes the 4_1 age class.

Table 13. Key areas to watch in 1984 where forecast is likely to be in error. Synopsis summarizing inconsistencies among forecast techniques.

System	Age Class	Forecast (Millions)	Synopsis	Possible Departure From Forecast
Kvichak	4_2	6.0	High R/S, high smolt, low return of 3_2, low 4_2 component in high seas forecast.	Lower Return
	5_2	3.0	Low smolt, large return of 4_2 in 1983, Kvichak 5_2 returns of this magnitude have occurred only in 1957 and 1961 following the 1956 and 1960 cycle year returns of 4_2 low 3-ocean high seas forecast.	Lower Return
Naknek	4_2	0.6	Possible large 1-check smolt outmigration in 1982.	Higher Return
	5_2	2.6	Low R/S, heavy 4_2 return in 1983, low 3-ocean high seas forecast.	Lower Return
	6_3	1.1	Low 3-ocean high seas forecast.	Lower Return
Egegik	4_2	0.4	Possible large return 1-check smolt outmigration in 1982.	Higher Return
	5_2	1.0	Low R/S, large of 4_2 in 1983, low 3-ocean high seas forecast.	Lower Return
	6_3	2.8	Record return of 5_3 in 1983, low 3-ocean high seas forecast.	Lower Return
Ugashik	4_2	0.4	Low R/S assumed for 1980 escapement, moderate return of 3_2.	Higher Return
	5_3	1.5	Higher R/S, low return of 4_3.	Unknown
	5_2	1.2	Low 3-ocean high seas forecast	Lower Return
Wood	4_2	1.4	Low 4_2 component in high seas forecast.	Lower Return
	5_2	2.6	Low 3-ocean high seas forecast.	Lower Return
Nuyakuk	5_2	2.0	Low R/S large return of 4_2 in 1983, low 3-ocean high seas forecast.	Lower Return

communication, Fisheries Research Institute, University of Washington, Seattle, WA 98195) feels that the Japanese were a little further offshore (south) than they normally sample. Rogers feels, based on the historical Adak sampling, that 1-ocean immature fish would be under-represented in the catches. If this were the case then the 2-ocean return should be more indicative other forecasts. Rogers feels that the 2-ocean immature sockeye were adequately sampled, and there is cause for concern in the low high sea's forecast 3-ocean returns.

The pattern of temperatures reported by the Japanese and supplemented by FRI observers on Russian fishing vessels in that area were very anomalous during the summer of 1983. Temperatures tended to decline as one moved offshore south of the Aleutians. Temperatures offshore were 5° below normal. This is cause for concern, as returns appear to have been depressed in the past by low temperature. Alternatively the distribution of immature sockeye may have changed in response to these temperature anomalies, in which case the CPUE reported by the Japanese may not be indicative of abundance.

The age composition of the 2-ocean returns based on the return of sibling age classes, and the age composition of the 1-ocean immatures caught in the Japanese high seas sampling indicate that returns of 4_2s may be depressed relative to the standard ADF&G forecast. This is a cause for concern since a relatively large return of 4_2s to the Kvichak is expected based on smolt studies. If this occurs there will be difficulties in 1985 meeting the peak-year escapement goal.

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